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Use of Chemical Fire Retardants Near Aquatic Environments 1/

by

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ABSTRACT

The toxicity of commercial fire retardants to fish and aquatic organisms was studied by the National Marine Fisheries Service 2/ and the Fish and Wildlife Service laboratories. 3/ Continuous flow bioassay tests demonstrated that commercial fire retardants were toxic to a variety of fresh water fish and a common fresh water crustacean (Gammarus). Increase of test water pH from 7 to 8 compounded the effect of the retardant. An increase in water temperatures did not cause significant differences in the toxic effect of the retardants. Tables and guidelines were prepared for field use.

1. The fire retardant compounds tested can be toxic to a variety of freshwater fish and at least one important crustacean, but precautionary procedures can prevent environmental problems.

2. The retardants with the higher pH formulations were more toxic to trout and Pacific salmon.

1/ Paper presented at the 104th annual meeting of the American Fisheries Society, September 10, 1974, Honolulu, Hawaii.

2/ Bureau of Land Management Research Contract Number: 53500-CT2-85(N)1973.

3/ Fish and Wildlife Service Fish Pesticide Research Laboratory, Columbia, Mo.

3. The pH of the receiving water or the retardant solution results in higher ammonia concentrations that increase the toxicity to fish and aquatic organisms.

4. Results of tests indicate that ammonia (NH_3) is the element of the compounds that cuased mortality at the dilutions of the retardants used for the tests.

5. The younger life stages of fish and aquatic organisms appear to be more sensitive to retardants than the older, larger fish.

6. An increase in water temperature from 10° to 20°C (50° to 68°F) did not significantly increase fish mortality; however, water temperature increases could alter tolerance of fish to compounds by causing sub-lethal stress.

7. Generally a decrease in retardant concentration enhanced fish survival time.

8. Recommendations and specific guidelines were prepared and issued to personnel using chemical fire retardants in the environment. The guidelines are now incorporated in some training programs of fire personnel in BLM and USFS.

RECOMMENDATIONS AND SPECIFIC GUIDELINES FOR USE OF CHEMICAL FIRE RETARDANTS IN THE ENVIRONMENT

The following facts, guidelines and precautions should be followed to minimize the entry of chemicals to streams or other water bodies when using fire retardants in or near areas which include important living aquatic resources.

FACTS

1. Commercial fire retardants used in forest and range fire suppression can be toxic to fish and other aquatic organisms.

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2. The fire retardants tested can be safely used for fire suppression around aquatic environments if management uses precautionary procedures and good operating techniques.

3. Ammonia is the toxic component causing the problem.

4. It is doubtful that other non-ammonia containing compounds will replace the ammonium phosphates and ammonium sulphates in the near future.

5. Aquatic animal mortality is likely to occur when the retardant is directly delivered to the water.

RECOMMENDATIONS AND GUIDELINES

1. Initiate a program to inform field and fire personnel, lead plane and air tanker pilots and fire managers of this potential problem.

2. Avoid dropping fire retardant directly into streams or other waters.

   a. Use alternative methods of fire line building such as ground crews, air and ground tankers and heavy equipment.

   b. Try to avoid establishing fire lines on small streams.

3. Air tanker filling and washdown locations should have precautionary drainage procedures and facilities to contain accidental spills. Use precaution in washing equipment.

4. Establish precautionary measures for accidental discharge of retardants directly into natural waters by protecting helitanker points and portable mixing locations where water is taken directly from the stream or lake.

5. Obtain advice on the type and importance of aquatic resources in the area of operation.

INTRODUCTION

Chemical fire retardants are commonly used in the United States to suppress forest, brush and range fires. The mixtures are applied with fixed wing aircraft, helicopters or ground vehicles. The use of chemical fire retardants is a big business that involves many dollars, people and much equipment.

Magnitude of use varies depending on the fire season. Estimates place annual use between 15 and 20 million gallons with an average expenditure of $10 million for delivered retardant on the fire. (Hartong 1971) The Bureau of Land Management, United States Forest Service and the California Division of Forestry are the principal agencies using these materials to fight fire.

With the increased use of retardants there quite naturally were occasions when the effects of the various retardants on the environment were questioned. The materials, during fire fighting operations, have many opportunities to come into direct contact with lakes, rivers, and streams that have important fish and other aquatic populations.

Several reports in past years have documented fish kills after application or accidents with fire retardants. Through these experiences it appeared that the major known effect retardant chemicals have on the environment may be through addition of substances in water that are toxic to fish and other aquatic life. (George, 1971)

In December, 1970 the initial meeting of a Federal interagency committee to study impact of retardants on the environment was held in the Portland Service Center Office of the Bureau of Land Management. Representatives of the Bureau of Land Management (BLM), U. S. Forest Service (USFS), and Fish and Wildlife Service (F&WS) were in attendance.

The many facets of the problem were reviewed at this meeting. Proposals were made for research, a plan of action was prepared and subject assignments were made for each agency.

The BLM agreed to develop a proposal for research that would test the toxicity to fish of the most commonly used fire retardants. The F&WS agreed to solicite help from their laboratories to test aquatic organisms and warm water fish. The USFS was to initiate a literature review and develop a complete problem analysis. The USFS also initiated plans to make field studies of retardant movement in the environment. The Literature Review (George 1971) indicated that the most likely toxic component of fire retardant formulations was ammonia (NH_3).

Objectives

The objectives of the laboratory study were determined in advance by committee members working in concert with scientists at laboratories of the National Marine Fisheries Service and the Fish and Wildlife Service.

1. Conduct bioassay tests to determine the effect of chemical fire retardants on juvenile rainbow trout and coho salmon from yoke sack fry to yearlings and available developmental stages of bluegills, fat head meadow, large mouth bass, and scuds (fresh water shrimp).

2. To determine the medium tolerance limit (TL_m) or (TC_{50}) i.e., the concentration of the tested retardants at which 50% of the test animals are able to survive for a specified time.

3. Determine if ammonia (NH_3) is the most toxic element of the compounds.

4. Test the synergistic effect of test water pH and temperature on the fishes tolerance to the compounds.

5. Make available the results of the bioassay to the Bureau of Land Management and the participating agencies and publish the information for

proper distribution to the other interested agencies and personnel.

Methods

Bioassay of Retardants to Determine Toxicity to Animals

A search of literature concerning toxicity of fire retardants to various animals revealed the lack of specific information on the subject. Data was available, however, for toxic levels of some of the major components of retardant formulations such as ammonia, ammonia sulphate and phosphates.

In 1971 the BLM proposed a cooperative study with the National Marine Fisheries Service (NMFS). The Bureau agreed to partially fund a two year study to determine toxicity of retardants to fish. A contract was negotiated with NMFS at their Prescott Environmental Field Laboratory, on the Columbia River, Oregon.

As a member of the fire retardant committee the F&WS through the Fish Pesticide Research Laboratory at Columbia, Missouri, agreed to do additional bioassay work that would include cold water and warm water fish and at least one invertebrate organism such as the scud, Gammarus pseudolimnaeus.

Other Research

In 1972 the research contract with NMFS was renewed to broaden the objectives of the study to determine if ammonia (NH_3) is actually the most toxic element of the compounds. It was also necessary from previous research to determine the synergistic effect of water pH and temperature on the fishes tolerance to the compounds.

In 1973 the U. S. Forest Service, Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon, initiated studies that were designed to follow the retardant through the forest floor and into streams and subsequent impact on stream benthic invertebrates. Changes in species diversity and population size and biomass are being monitored in connection with changes in stream chemistry. These are long range studies. Test applications have been made and the study is in progress.

Procedures and Equipment

In both the NMFS and F&WS studies standard methods of bioassay were used. The four retardants used for the test were the ones commonly used in the United States. They were Phos-Chek 202XA and 259 produced by the Monsanto Company and Fire-trol 931 and 100, which are produced by the Chemonics Industries. These manufacturers cooperated extensively, which enhanced the conduct of the tests described in the report.

In the static and flow-through bioassay tests by the NMFS in Oregon, samples of no less than ten fish each were transfered in covered plastic containers from the pre-test holding tanks to each test tank. The concentration of each retardant to be tested had been attained in each test tank prior to introducing the animals. In the flow-through tests water mixed with a fire retardant to the desired concentration was supplied to each tank at the rate of approximately 1 liter per minute. A complete exchange of water was made every three hours. Two air stones in each tank, plus the water exchange, maintained the dissolved oxygen content at 100 percent saturation or higher. Correct amounts of retardant and water were delivered by specialized apparatus constructed at the laboratory. The dry powder or the liquid concentrate as shipped by the supplier was used for the tests, not the formulation as mixed for field application. A comparison is shown in Table 4.

Coho salmon and rainbow trout were used for the tests by the NMFS. Juvenile fish of two size classes, yearling and sub-yearling were used. Fish ranged in size from 49-200 milimeters (1.9-7.9"). No mortality occurred during transportation of the fish from the hatcheries to the laboratory and less than 1 percent was experienced during the pre-test holding time. Water temperature was controlled for the desired test with temperatures of 10, 15, and 20 degrees centigrade. (50°, 59°, 68° Fahrenheit, respectively)

At the Columbia Missouri Laboratory of the Fish and Wildlife Service, static and flow-through toxicity tests were conducted generally as outlined in the literature on Standard Bioassay Methods. (Apha 1971, Mount and Bruno 1967 and Lennin and Walker 1964) Flow-through techniques were conducted with Fire-trol 100 only. The apparatus was approximately the same design as that used in the National Marine Fisheries Service experiments. All data at both laboratories were submitted for statistical tests to determine 95 percent confidence intervals. Detailed description of procedures, apparatus and test animals will be or have been reported by the NMFS and Columbia, Missouri Fish Pesticide Laboratory of the F&WS.

Results of Studies

General Toxicity

The bioassay studies conducted by the NMFS and F&WS indicate that fire retardants, in general, can be toxic to fish and other aquatic organisms when applied in high concentrations in localized areas.

All laboratory tests were conducted where temperature, pH and size of test animal were controlled. These factors of course, are variable in the environment and some, such as pH, have a definite effect on rate of fire retardant toxicity to aquatic animals.

Fish

Values for lethal dosages of retardants are expressed in the median tolerance limit (TL_m), which is the concentration of the tested retardants at which 50 percent of the test animals are able to survive for a specified time. Some laboratories express the same lethal dosage as lethal concentration (LC_{50}), however, each represents approximately the same end point in toxicity to animals.

During the first (1972) tests of the NMFS there was no obvious correlation between tolerance to retardants and fish species or size of fish. In these tests any relationship between size of fish was probably masked by pH differences among tests. pH had a profound effect on the relative toxicity of all the compounds to fish.

A summary of the relative toxicities of fire retardants obtained in the 1972 NMFS tests are presented in Table 1. As stated in the procedures, the tests were conducted with the products as received from the supplier and not the mixture used for field application. (See Table 4)

TABLE 1. The median 24 hour acute toxicity median tolerance limit (TL_m) concentration values for four fire retardants in NMFS 1972 flow-through tests. The TL_m values are reported as parts per million (ppm) as diluted from the concentrates of the retardants as received from the supplier and before dilution for field use. (Blahm, 1973)

	FIRE RETARDANT TYPE Concentrations in ppm (mg/l)			
Test Fish	Phos-Chek 259	Phos-Chek 202	Fire-Trol 931	Fire-Trol 100
Coho Yearling	160	191	506	450
Coho Sub-yearling	160	135	935	940
Rainbow Yearling	128	138	572	610
Rainbow Sub-yearling	148	120	836	~590

Table 2 is a summary of rainbow trout and coho salmon egg and juvenile limits of toxicity as determined by static tests at the F&WS Fish Pesticide Laboratory at Columbia, Missouri. Flow-through tests were only conducted at this laboratory with Fire-trol 100. The summary of flow-through test results is in Table 3.

Flow-through and static tests were made with only one invertebrate aquatic organisms the common crustacean, scud (Gammarus pseudolimnaeus). The scud, commonly called "fresh water shrimp" is an important aquatic food for fish.

In general in the F&WS tests it was found that relative toxicities were highest for scuds and egg-sack fry of both coho and rainbow trout.

The studies indicate that a critical period for mortalities to fish from fire retardants may be when eggs or newly hatched fry are in the gravel or recently emerging from gravel. The data also indicate that some invertebrates in the aquatic environment may be more vulnerable to retardants than fish.

Use of retardants in watersheds where water supplies are used for fish culture would warrant special consideration during periods of egg hatching and development of fry. LC_{50} values for these organisms are also presented in Table 2 and 3. Fish cultural stations, especially in the west, may contain large quantities of fall spawning salmon eggs that are in various stages of development. The ova and fry would be very vulnerable to toxic elements in the water supply.

TABLE 2. The median 24 hour LC_{50} (TL_m) acute toxicity of four formulations of chemical fire retardants to five species of fish and one invertebrate as determined by the static technique[1/].

	FIRE RETARDANT TYPE Concentration in ppm (mg/l) [2/]			
	Phos-Chek		Fire-trol	
Test Animals	259	202	931	100
Coho salmon	ppm (mg/l)		ppm(mg/l)	
Yolk sac fry	> 200	175	> 500	160
Swim-up fry	175	210	1,050	1,100
Fingerling	247	355	>1,325	> 1,300
Rainbow trout				
Yolk sac fry	> 200	140	>500	158
Swim-up fry	102	125	800	900
Fingerling	172	265	>1,000	> 1,000
Bluegill sunfish	600	840	>1,500	> 1,500
Fathead minnows	470	820	>1,500	>1,500
Largemouth bass	720	840	>1,500	>1,500
Scud [3/]	>100	>100	>100	>100

1/ F&WS, Fish Pesticide Laboratory, Columbia, Missouri
2/ Water pH; 7.4: alkalinity: 35 mg/l; total hardness, 40 mg/l at 20° C (warm water fish), 18°C (scud), or 10°C (cold water fish)
3/ Gammarus pseudolimnaeus (Freshwater shrimp)

TABLE 3. Toxicity of Fire-trol 100 to rainbow trout, coho salmon and scud under flow-through test condition[1/]. The formulation as received by the supplier.

Test Animal	Median LC_{50} Values in mg/l (ppm)[2/] 96 hr	7 day	14 day
Rainbow trout			
Eggs	22	22	17
Yolk sac fry	-	-	37
Swim-up fry	67	61	31
Coho salmon			
Yolk sac fry	275	275	89
Scud	250	250	71

1/ F&WS, Fish Pesticide Laboratory, Columbia, Missouri
2/ Test water pH 7.4; alkalinity 237 mg/l; hardness 272 mg/l at 16°C.

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Environmental Conditions that Change Toxicity

Water Volume

Water volume is one of the primary factors in determining the toxic effect of individual retardant applications to aquatic animals. Larger streams, lakes and reservoirs would provide a significant dilution factor and an escape area for most mobile organisms. Aquatic animals in small streams and intermittent water courses would be the most vulnerable. Generally the retardants tested are not extremely toxic so dilution in larger streams can be an important factor in reducing toxicity. Statistics on the monthly average flows of streams in watersheds exposed to retardants would be of basic value to fire personnel.

Water Chemistry

As a result of the tests, an analysis of variance demonstrated that the toxic effect of retardant type to fish in test water pH was significant. An increase in test water pH caused an increase in fish mortality in tests with either retardant.

The significant increase in compound toxicities associated with an increase in pH from 7 to 8 is related to the ammonia potential of the retardants. The concentration of free ammonia (NH_3) in any of the retardant - water mixtures is dependant on the amount of ammonium, (NH_4^+) contained in the retardant and the pH of the retardant - water solution. The retardants used in the tests have the potential to disassociate to the levels of ammonia as shown in Table 4.

TABLE 4. Percent potential ammonia in four commercial fire retardants. (Blahm, 1974)

Retardant	Percent Potential Ammonia
Fire-Trol 931	12.0
Fire-Trol 100	16.0
Phos-chek XA	22.4
Phos-chek 259	24.5

The toxic effect of ammonia to fish and other aquatic organisms is well documented. (McKee and Wolf 1971) (FAO 1970) The ratio of ammonium to ammonia in an aqueus solution is determined by the pH of that particular solution. A 10-fold increase in unionized ammonia is effected by a pH increase of one unit; e.g. pH 7 to pH 8. After considerable testing the toxic effect of the fire retardant compounds was essentially related to the amount of ammonia in the retardant formulation. This fact substantiated the hypothesis that ammonia is the most toxic agent in the retardants.

The pH level of receiving waters is extremely important in determining the toxicity of retardants to fish and other aquatic organisms. (Blahm 1974)

In general, waters formed at higher elevations, originating from snow packs or heavy rainfall are fairly neutral with the pHs in a range of 7.0 - 7.2. We would expect these waters to have the least synergistic effect with introduced fire retardants.

Some of the lower elevation waters are exposed to mineral deposits that result in water with higher pH. We could expect pH in the range of 7.3 to 8 in these waters.

Temperature

The results of using various test water temperatures did not show a statistical difference in mortalities. However, optimum temperatures for salmonids is approximately 12 degrees centigrade (54°F). Increases in water temperatures above the optimum tend to stress the animal and decrease it's resistance to other harmful environmental variables. The synergistic effects of higher water temperatures and the retardant compound might not be manifested by death, but sub-lethal stress could exist. (Blahm, 1974) Water temperatures of small streams can and are often increased during fires.

Size and Species of Fish

Juvenile coho salmon used at the NMFS, Prescott, Oregon, facility on the Columbia River did not indicate a significant change in mortality or toxicity due to the size of coho or rainbow trout used in the tests. Yearling coho ranged in size from 106 to 131 mm (4.2 to 5.2 inches) and sub-yearling coho ranged from 49 to 70 mm (1.9 to 2.8 inches). Yearling rainbow trout ranged from 132 to 201 mm (5.1 to 7.9 inches) with an average of 171 mm (6.7 inches). Sub-yearling rainbow ranged from 50 to 86 mm (2 to 3.4 inches) with an average of 66 mm (2.6 inches).

In tests at the F&WS Columbia, Missouri Fish Pesticide Research Laboratory the early life stages of fish appeared to be more sensitive to the retardants tested than the older larger fish. The single species of invertebrate (scud) in static tests was more sensitive than the fish to all four retardants. The research indicates that personnel familiar with the aquatic ecosystem and life histories of important fish and aquatic organisms in broad areas of operation could be very helpful to the fire suppression personnel, that must consider broad ecological problems. Consideration should be given to have a local fisheries biologists available for consultation during serious outbreaks of fire if retardants are to be used for control.

Relative Toxicity with other Chemicals Used in the Environment

The results of the tests indicate that ammonical fire retardants are toxic to fish. Comparing their toxic levels to other compounds such as DDT with a TL_m value of approximately three parts per trillion and copper and zinc at 30 and 1000 parts per billion, respectively, we see that the relative toxicity of the retardants is much less than the more toxic pesticides and heavy metals. In most instances TL_m values were 100 parts per million or greater and ranged to over 1,500 parts per million for the tested fire retardants. The TL_m values of retardants for fish and aquatic life are similar to those published for the herbicide 2, 4-D. TL_m values of 2, 4-D range from 100 to 500 ppm. The rate of application of fire retardants on a single location is, however, much higher than pesticides.

Comparative Toxicity

The study included a comparison of the toxicity of retardants as received from the supplier and as mixed for field application.

Phos-chek XA is mixed for use in the field at the ratio of 1.14 pounds per gallon of water, Phos-chek 259 at 1.60 pounds per gallon of water, Fire-trol 100 at 3.78 pounds per gallon and Fire-trol 931 diluted at the ratio of 1 part concentrate plus 4 parts water.

The toxicities or TL_m established in the initial tests reflect tolerance levels resulting from dilution of the retardant concentrates as received from the supplier. A factor can be applied to these TL_ms to convert them to ppm of the "as mixed for field application" (AMFA) form of the compounds. Table 4 presents the 96 hour TL_m (acute toxicity) as obtained from solutions of two fire retardants and also the calculated toxicities in ppm "as mixed for field use." The table is a tabulation of the differences in toxicity of two basic fire retardants and the importance of the receiving water pH in determining possible fish mortality.

Table 5 - The acute toxicity for juvenile rainbow trout bioassayed in dilutions of two fire retardants.1/ The retardants as packaged by the manufacturer were diluted to test concentrations. Also shown is a calculated concentration of toxicities of each retardant as mixed for field use for application to fires. (Blahm, 1974.)

Test Water Temperature		FIRE RETARDANT							
		PHOS-CHEK XA				FIRE-TROL 931			
		Water pH				Water pH			
		7		8		7		8	
		Conc. 2/	AMFA 3/	Conc.	AMFA	Conc.	AMFA	Conc.	AMFA
°C	°F	96 hour TL_M - ppm				96 hour TL_M - ppm			
10	50	283	2349	154	1278	1497	5838	326	1271
15	59	224	1859	139	1154	1238	4828	150	585
20	68	224	1859	93	772	1076	4196	63	246

1/ Tests were done at pH 7 and 8 and at water temperatures of 10, 15, and 20 C.

2/ Diluted from concentrate as packaged by manufacturer.

3/ Calculated ppm dilution of "as mixed field application."

Distinctive Behavior of Fish Exposed to Retardants

At retardant concentrations not causing a 100 percent mortality within a few hours, a loss of equilibrium was evident in most test fish. Loss of equilibrium was also noted in fish tested at higher concentrations before they died within a few hours. In these higher concentrations most of the dead fish exhibited swelling of the body, however, this was not characteristic of fish that succumbed in a short time. In a field situation the characteristic loss of equilibrium and swelling of the body of fish may be indicative of retardant toxicity.

Water Volume, Flow and pH Effect on Fish

The problem of predicting fish mortality in advance or evaluating a previous retardant drop on a stream or river has been researched by the Forest Service, United States Department of Agriculture. (Van Meter and Hardy 1973) The authors have developed a method to compute the concentration of toxic material that may enter streams at a given point and the dilution action of flowing streams. The Van Meter - Hardy method enables fire planning and fire suppression personnel to predict, in advance, the probable effect of an application of retardants to the aquatic environment.

Figure 1 and 2 are graphic illustrations of the time required to cause 10 per cent mortality of fish from two retardants under different water pH. The dotted line in each graph extends from the last concentration of which 10 per cent mortality occurred to the next lower concentration (at which no mortality occurred) and the end of the test (5760 minutes).

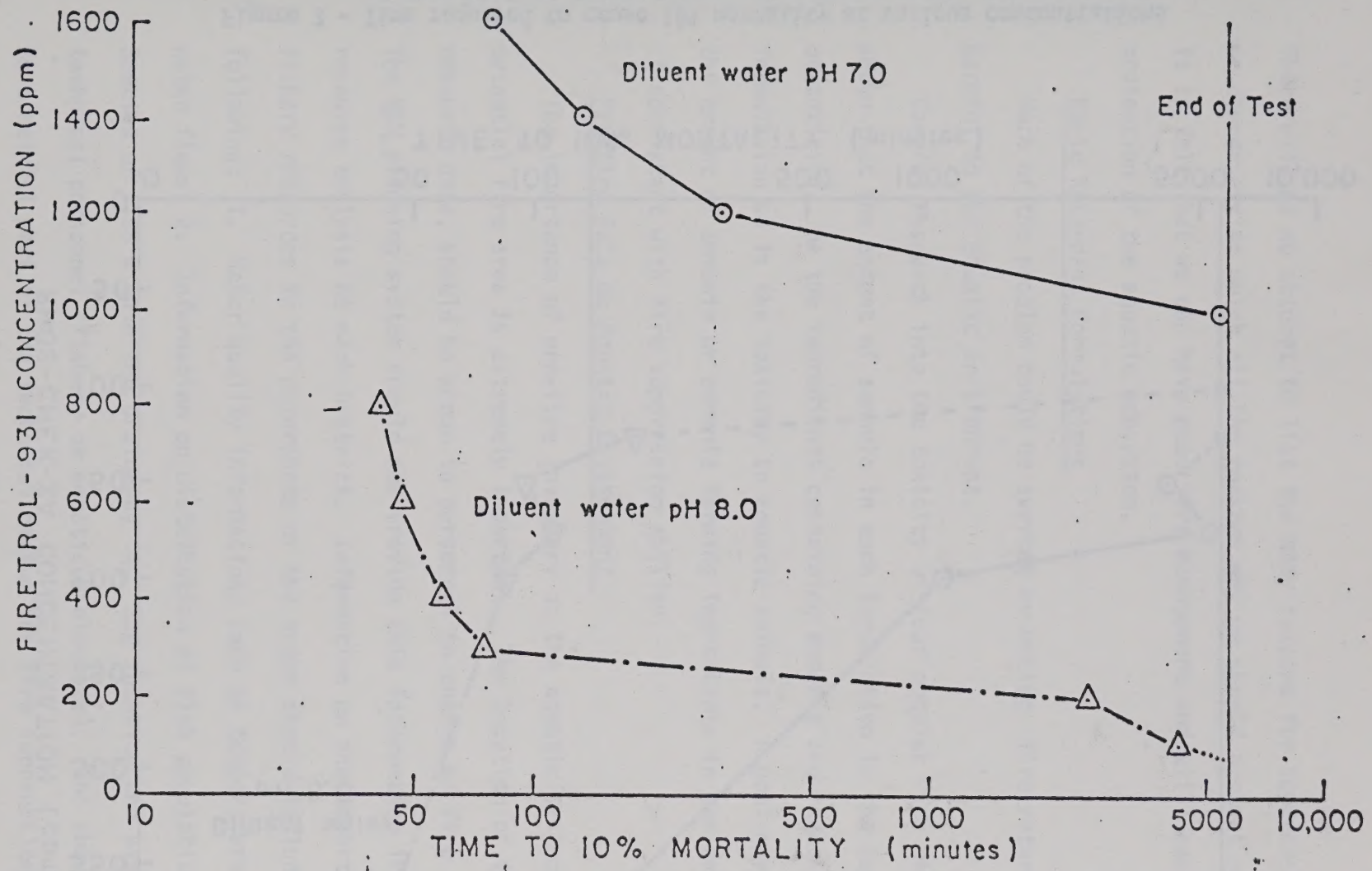

Figure 1 - Time required to cause 10% mortality at various concentrations of FireTrol 931 diluted (from the concentrate) with water of pH 7 and 8. Theoretically less than 10% mortality would occur at concentrations and times below the line. (Blahm, 1974.)

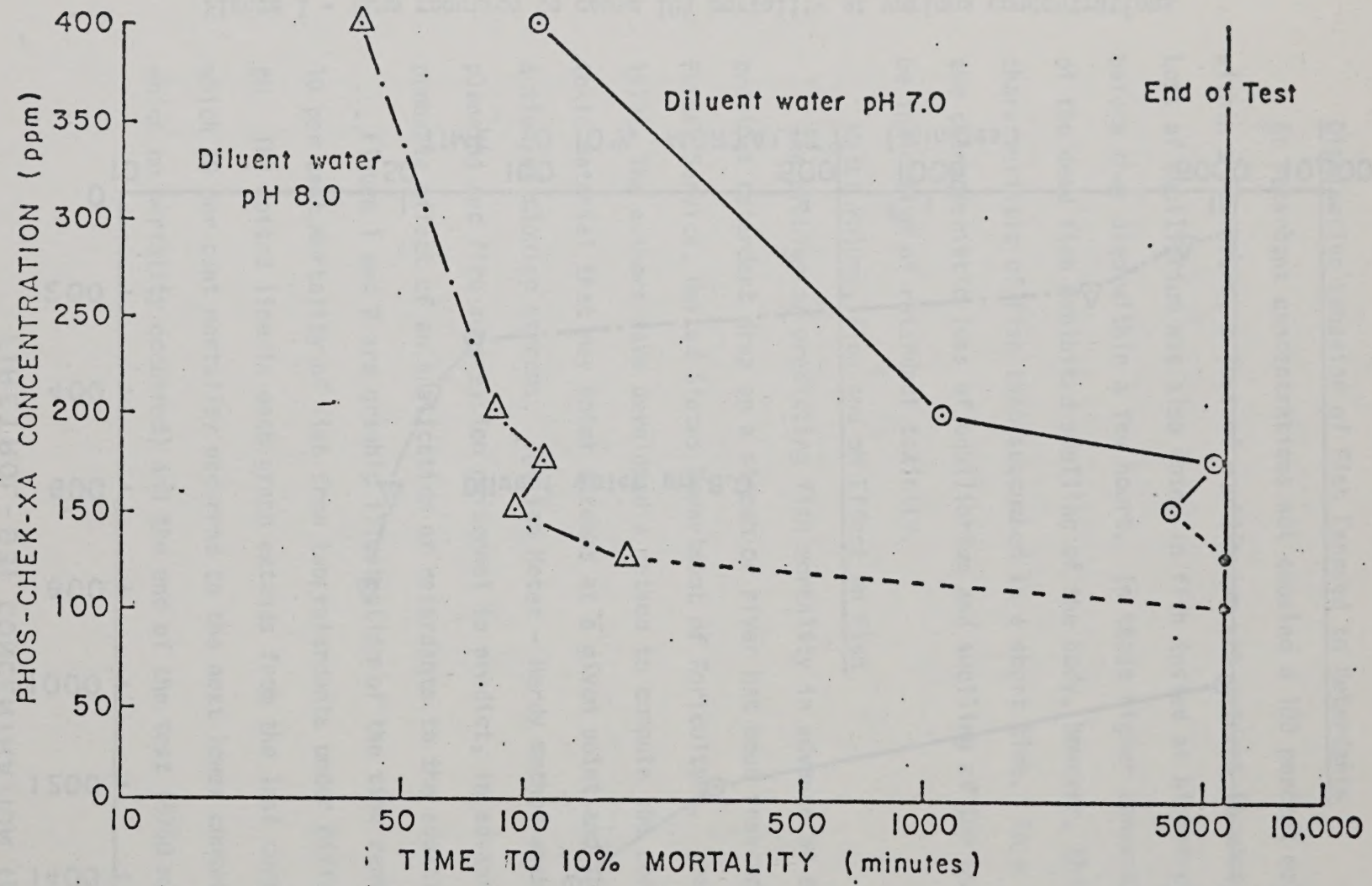

Figure 2 - Time required to cause 10% mortality at various concentrations of Phos-Chek XA diluted (from the concentrate) with water of pH 7 and 8. Theoretically less than 10% mortality would occur at concentrations and times below the line. (Blahm, 1973.)

There will be no attempt to list the many reasons for suppressing fire or conversely to weigh all the reasons why we should protect aquatic animals. It is felt that we can have good fire management and still have basic protection of the aquatic ecosystem.

Basic Retardant Formulations

Much of the problem could be averted by making fire retardants less harmful to the aquatic environment.

Careful research into the toxicity of four popular fire retardants has shown that the amount of ammonia in each formulation is the key to the degree of toxicity. As the ingredients containing ammonia are reduced in the formulation so is the toxicity to aquatic animals. A goal may be to reduce the amount of ammonia or ammonia forming ingredients in the retardants if consistant with fire suppression ability.

Pre-fire Data on Aquatic Environment

The importance of pre-fire inventory on the aquatic systems in the potential fire area is extremely important. The location of the aquatic resource data, should be known to personnel in charge of fire suppression. The BLM planning system should now provide this information in the unit resource analysis at each District. Information on the importance of fishery resources in the watersheds of the areas should include the following: 1. Water quality information, such as temperature, pH and water flows; 2. Information on distribution of fish populations; 3. Species of fish within the drainage; 4. The location and availability of technical personnel (fishery or aquatic biologists). The above items would be a helpful part of the technical backup for fire suppression crews.

Fire Map Data Points

The fire suppression plan in any area would be improved if important aquatic areas with significant resources could be designated on maps. Critical areas, such as fish hatcheries should be shown on maps or overlays.

A narrative could supplement the map by listing important aquatic resources and pertinent information on species, abundance and critical periods in life history. Water chemistry and flow data could also be detailed in the narrative.

Technical Assistance

Provide fire protection personnel with a list of all agencies and personnel qualified to advise on aquatic problems. The list should be made a part of the pre-suppression information and should include the names, addresses and telephone numbers of key personnel and agencies.

List of Agencies and Personnel Qualified to Advise on Aquatic Resources

Federal Agencies

Bureau of Land Management

Denver Service Center, Standards and Technology, Wildlife Section;

Oregon State Office, River Basins or Wildlife Staff, Portland, Oregon;

Wildlife or Fisheries Specialist, each State Office of BLM.

National Marine Fisheries Service, Regional Offices.

Fish and Wildlife Service, Regional and Area Offices.

U.S. Department of Agriculture, Forest Service, Wildlife Staff, Regional and Forest Headquarters.

State Agencies

Each state wildlife or fish and game agencies director of fisheries.

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